CdZnTe-AGIPD characterization at Petra III

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1) DESY. 2) UHH 3) ESRF The European Synchrotron 4) European XFEL 5) UKRI Science and Technology Facilities Council

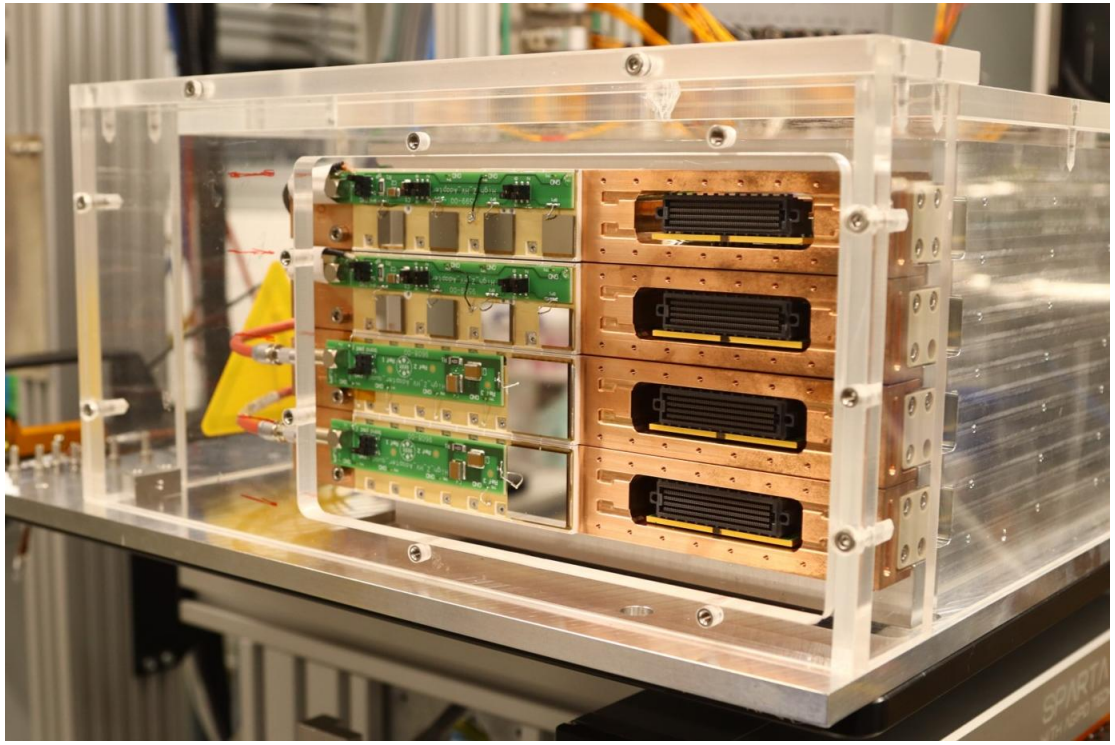
AGIPD

27th International Workshop on Radiation Imaging Detectors – 02/07/2026

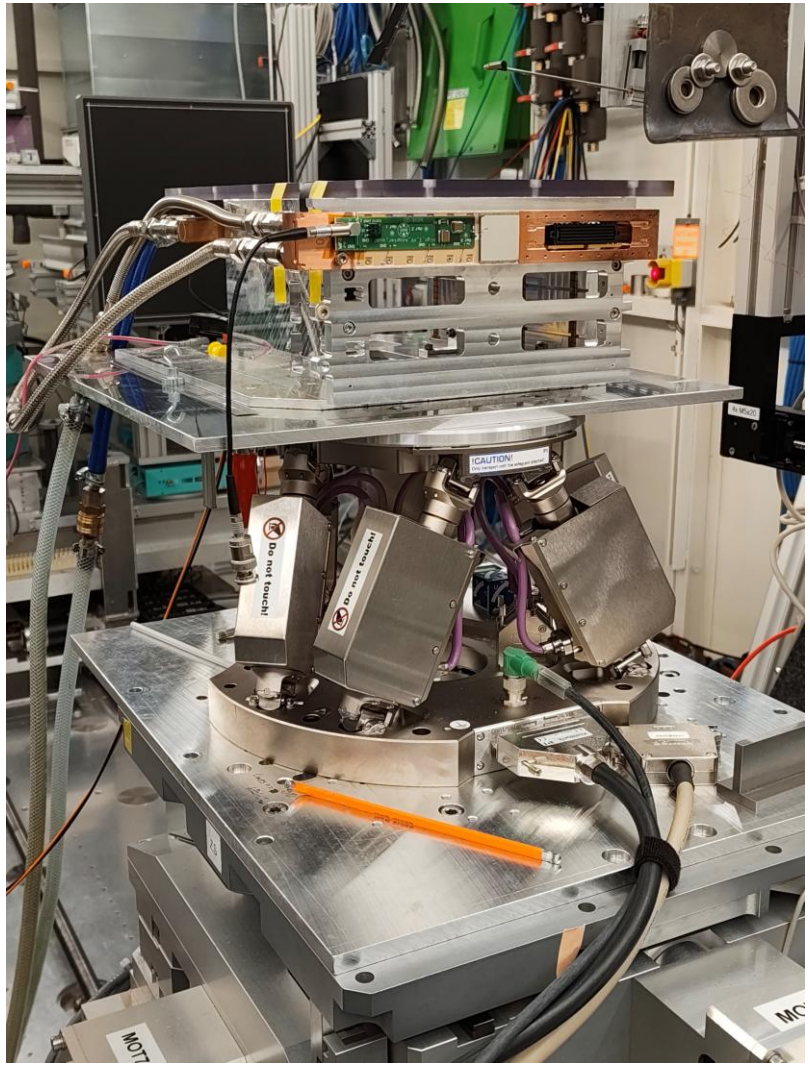
DESY.

Context

- Electron-collecting AGIPD ASIC for high photon energy applications at High Energy Density (HED)/EuXFEL
- High-Z AGIPD prototype modules with GaAs and high-flux CZT sensors developed and mounted in AGIPD mini-half structure
- Prototype tested previously at HED in dedicated beamtimes
- Single module with high-flux CZT tested at P07/Petra III in 10/2025:
  - More stable beam conditions
  - Higher setup flexibility



Setup

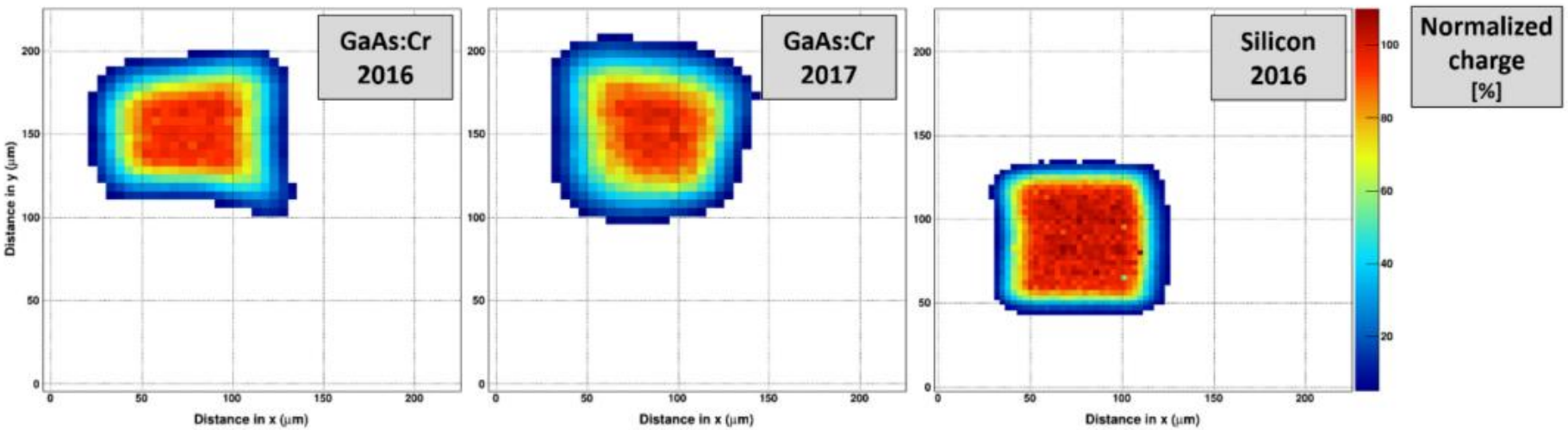


- Single module mounted on a mini-half test structure
  - **High-flux CZT** quad sensor (128x128 pixels), 2mm thick
  - Bias voltage: -1000V
- Structure mounted on the beamline hexapod stage
  - High precision translation and rotation
- Possibility of focusing the beam and perform sub-pixel 2D scans
  - Compound reflective lenses (CRLs) → 20x2 μm^2 beam (HxV)
  - Pixel pitch: 200 µm
- Storage ring in 40-bunches mode (equivalent pulse rate 5.2 MHz)
- 73 keV monochromatic beam

Measuring CZT sub-pixel mapping

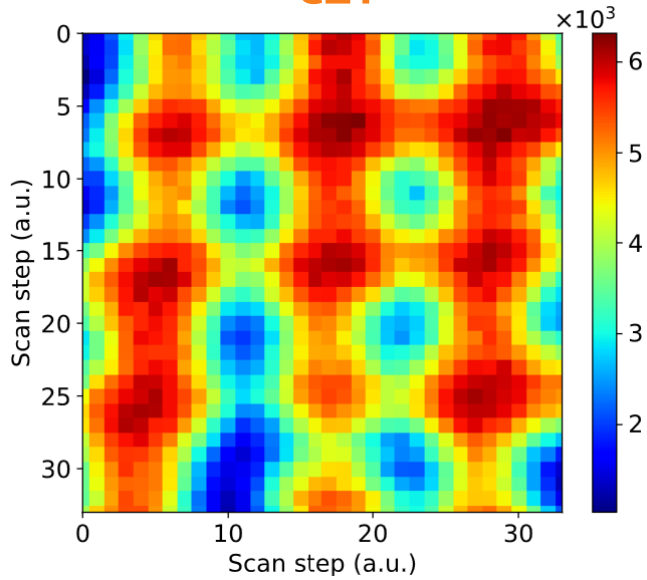
Motivation: previously reported results for High-Z materials show that the electric field non-uniformity can provoke a deformation of the pixel area

GaAs GaAs Si



D. Greiffenberg et al. *Sensors* **2021**, *21*, 1550. https://doi.org/10.3390/s21041550

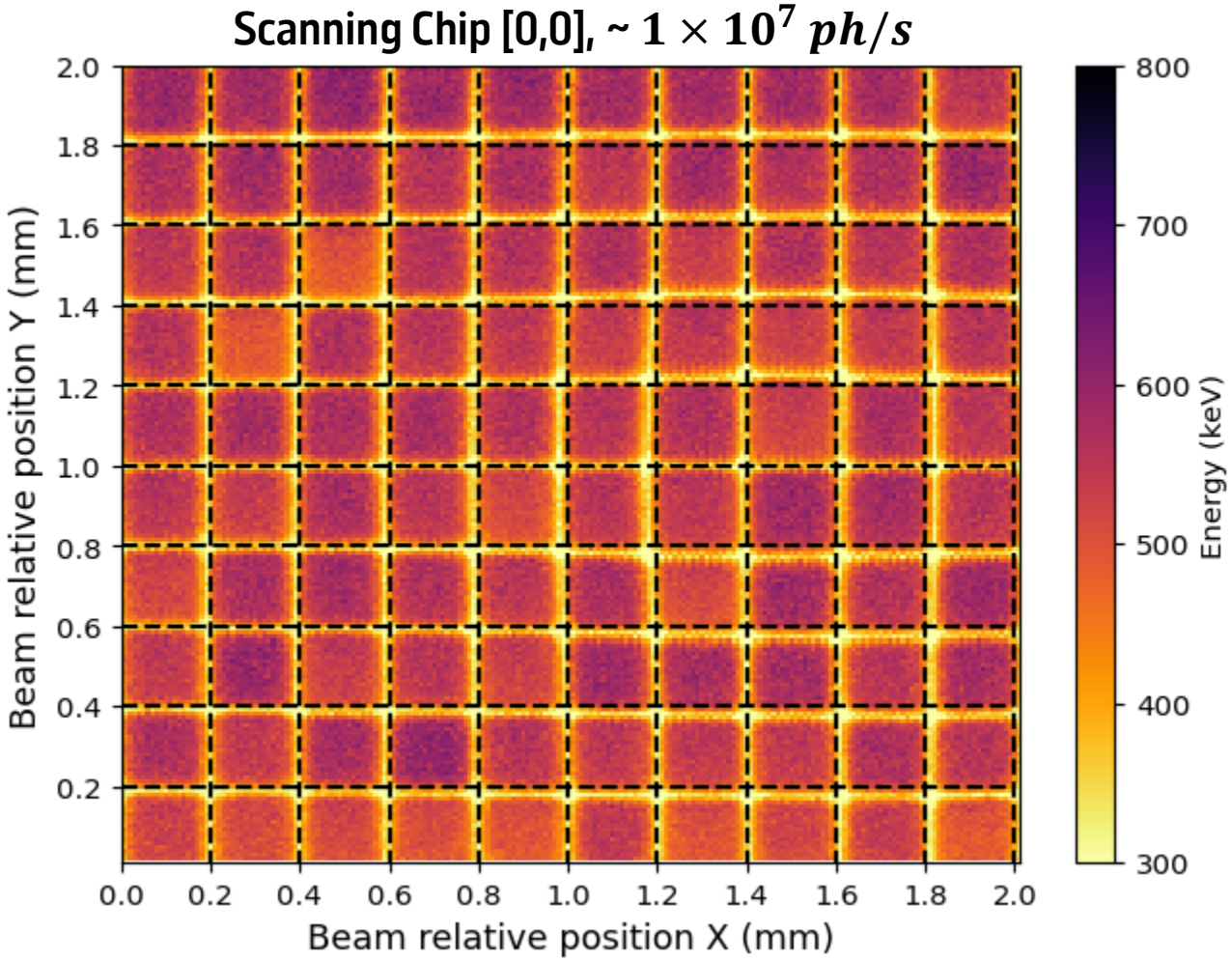
CZT



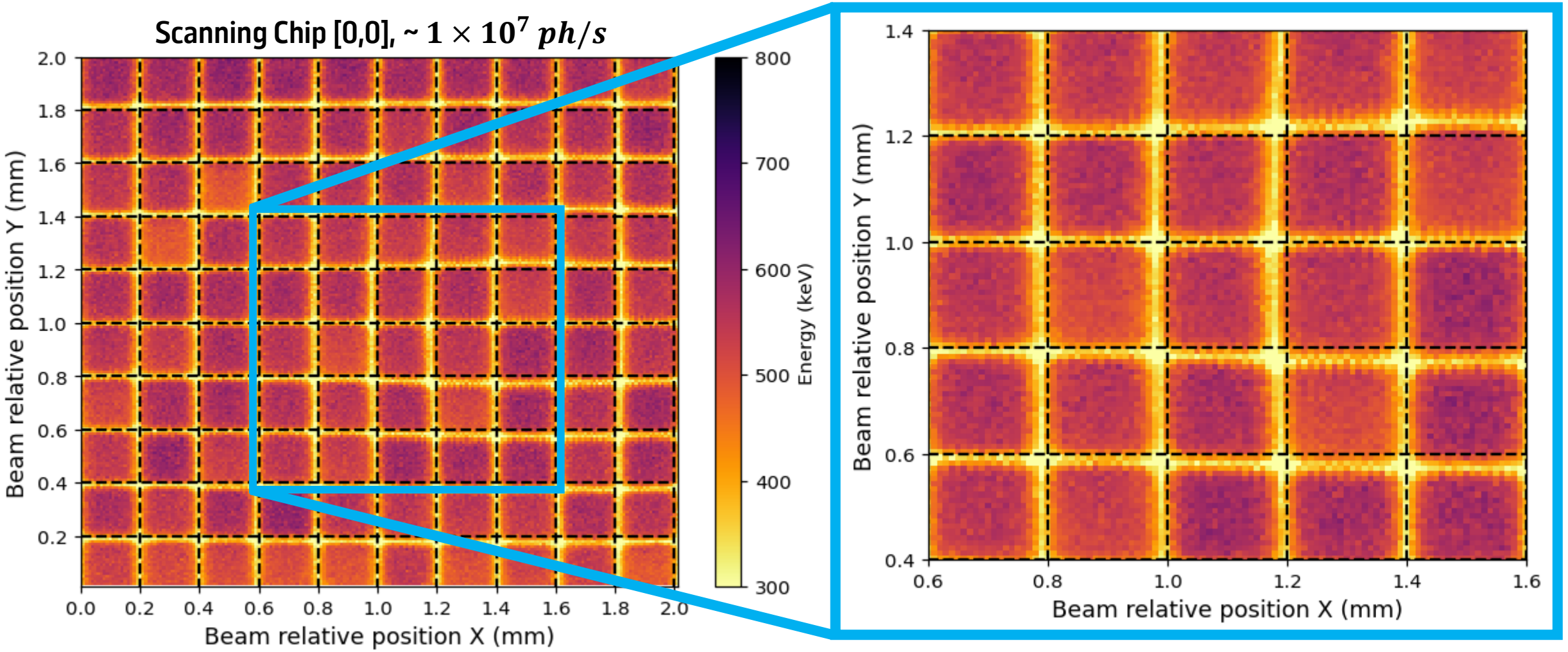
S. Tsigaridas et al., *Sensors* **2021**, *21*, 2932. https://doi.org/10.3390/s21092932

Procedure: AGIPD is charge integrating → plot the **maximum signal** per position highlights the edges

Results: CZT sub-pixel mapping



Results: CZT sub-pixel mapping



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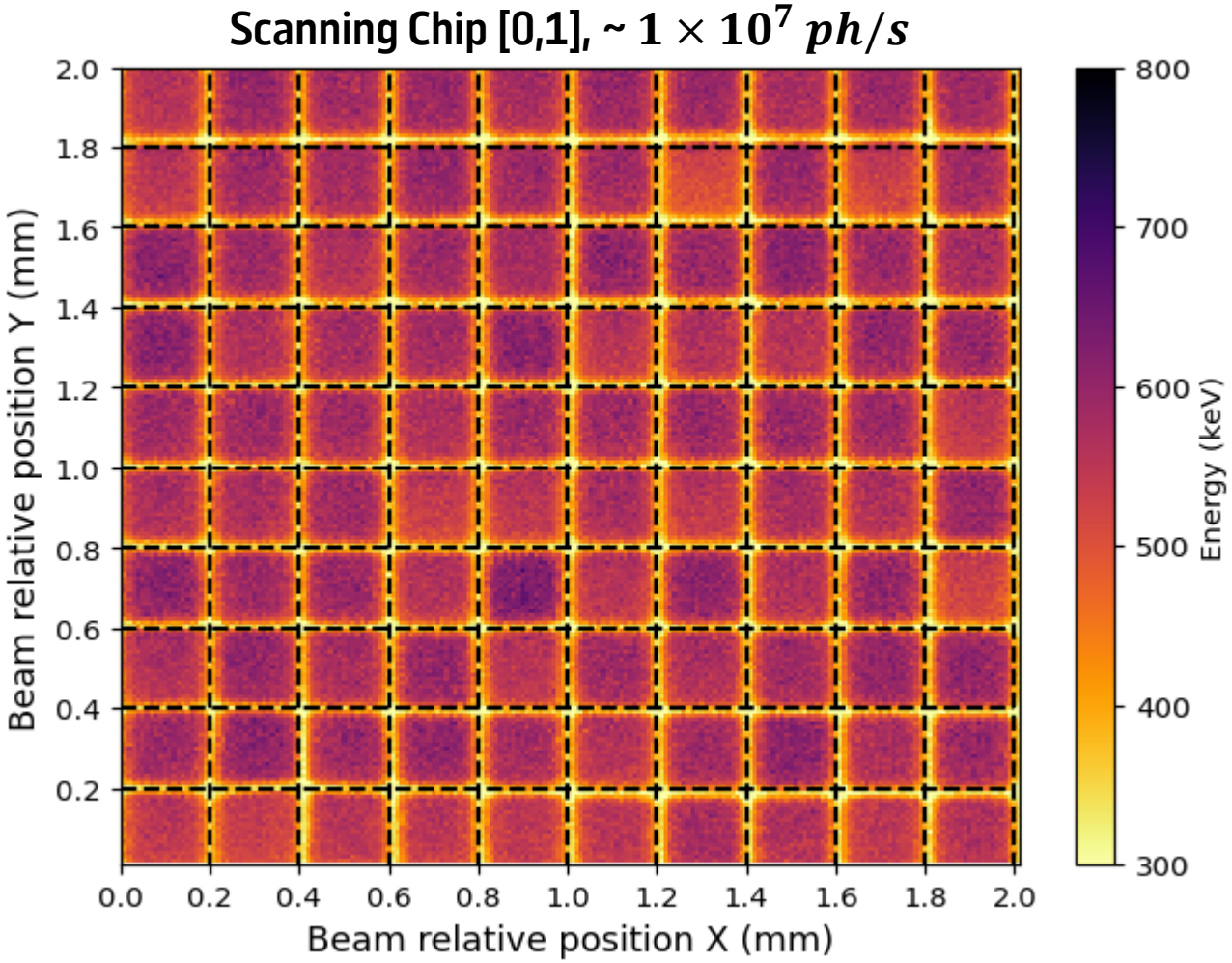

$\sigma_H = 3.01\ \mu m$ $\sigma_V = 2.80\ \mu m$	$\sigma_H = 3.27\ \mu m$ $\sigma_V = 2.87\ \mu m$
$\sigma_H = 5.52\ \mu m$ $\sigma_V = 6.96\ \mu m$	$\sigma_H = 3.46\ \mu m$ $\sigma_V = 2.96\ \mu m$

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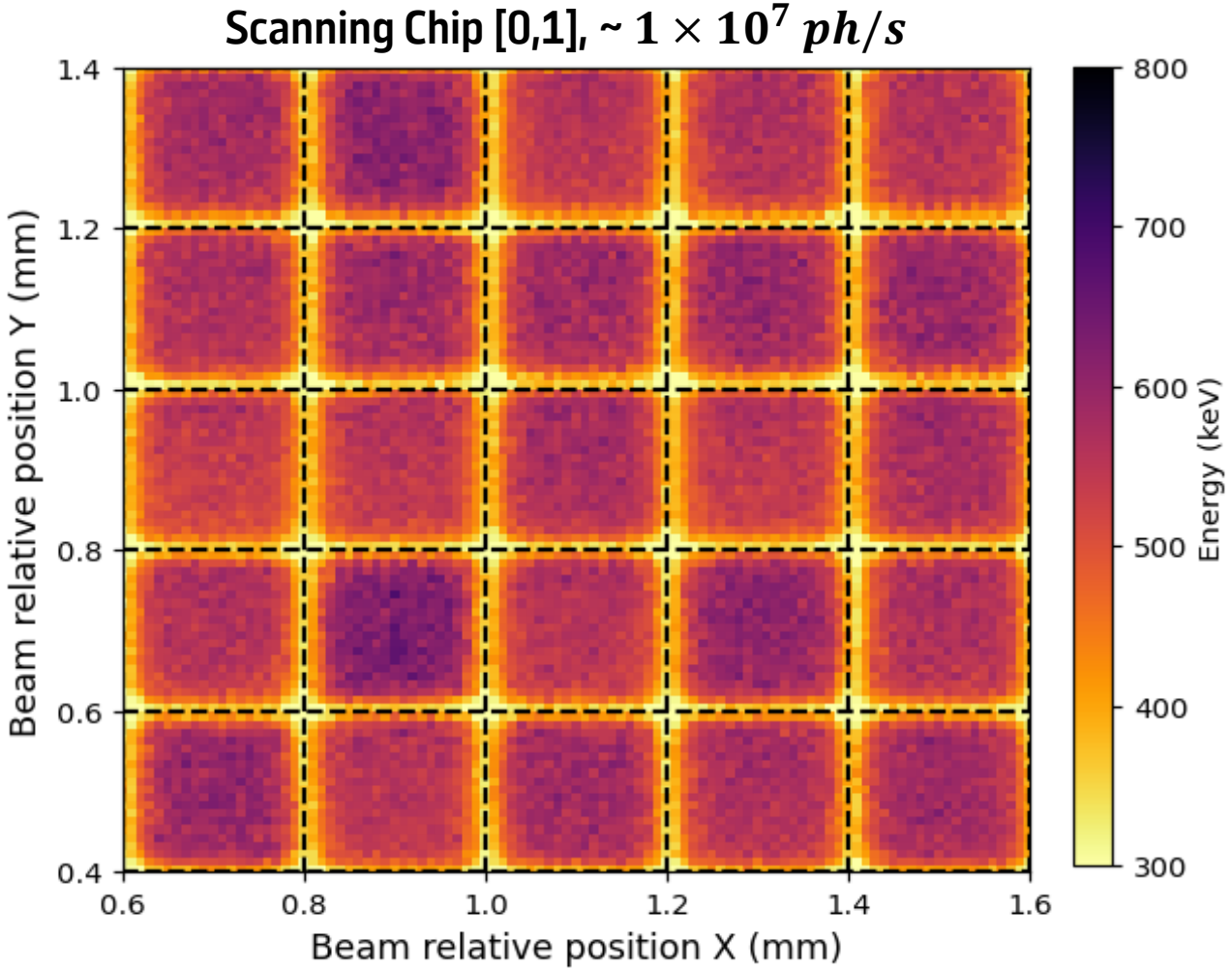

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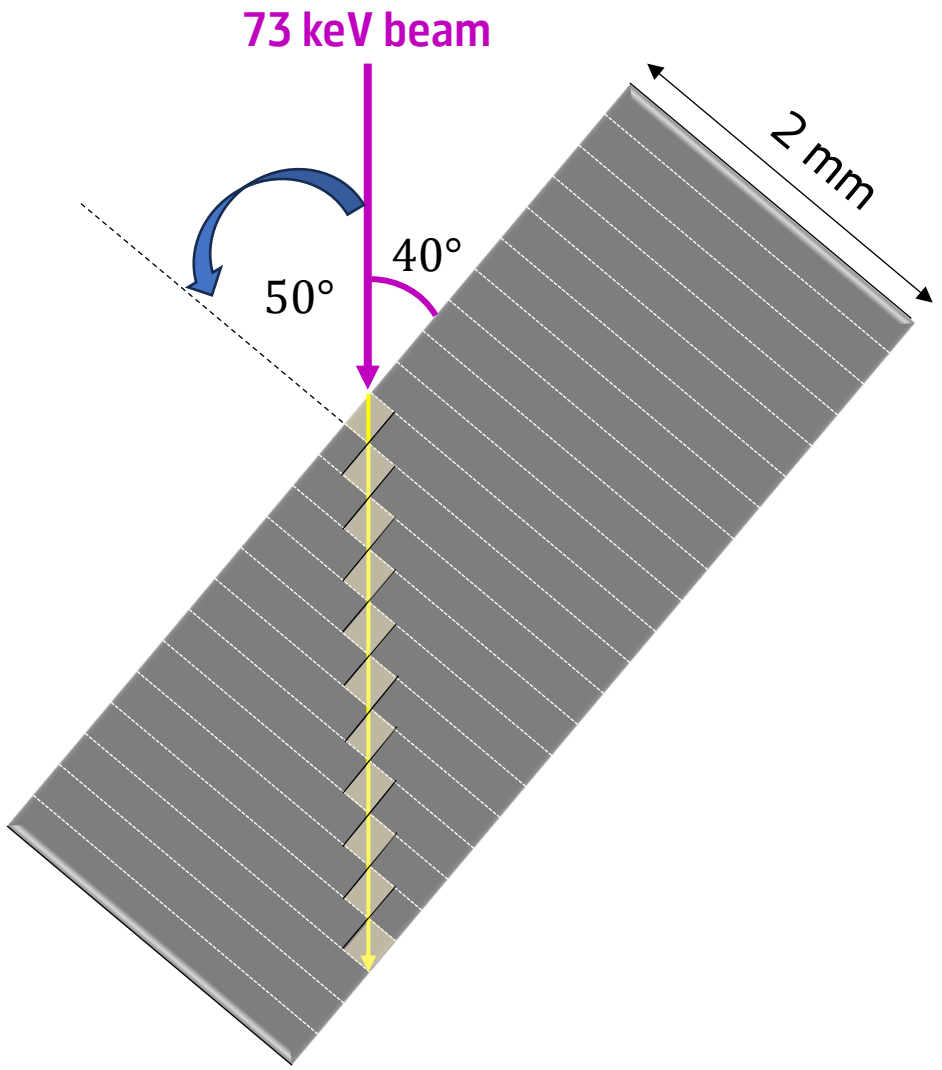
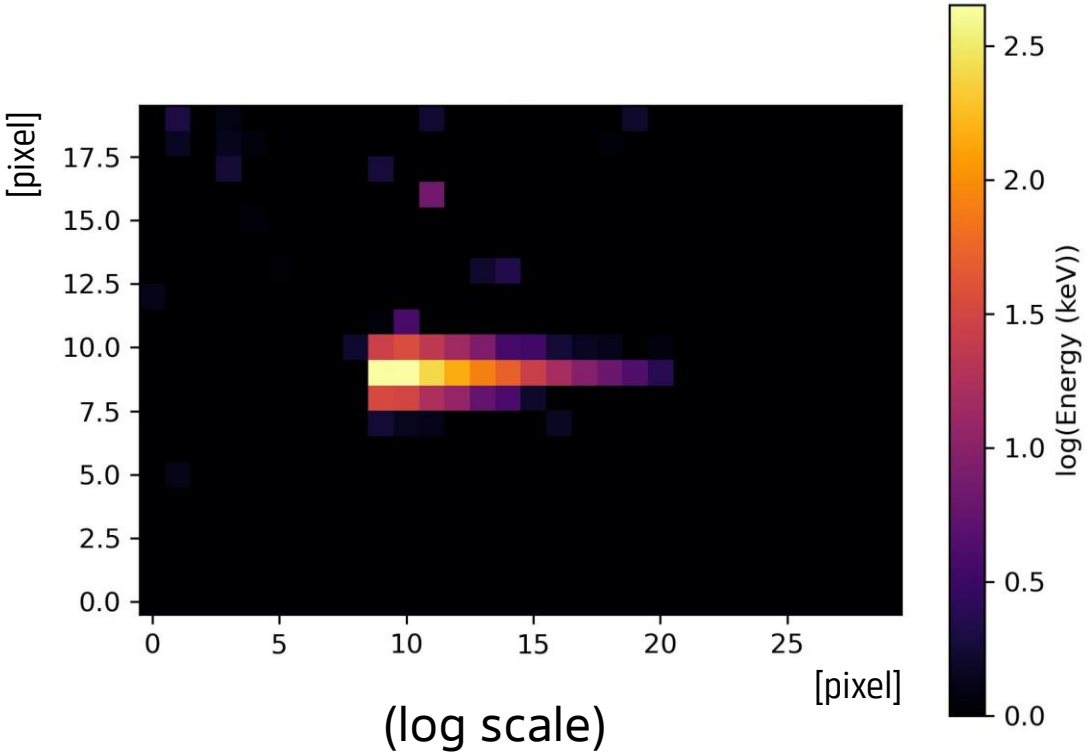
Performing an angle-on measurement

- Detector plane rotated 50° → focused beam at 40°
- Full beam path in the sensor: $\frac{2\ mm}{\sin 40°} = 3.11\ mm$
- **Goal**: evaluate the charge collection efficiency as a function of the **interaction depth**
  - The exponential mass attenuation of the photons has to be considered
- Tested for several attenuators and different gain modes

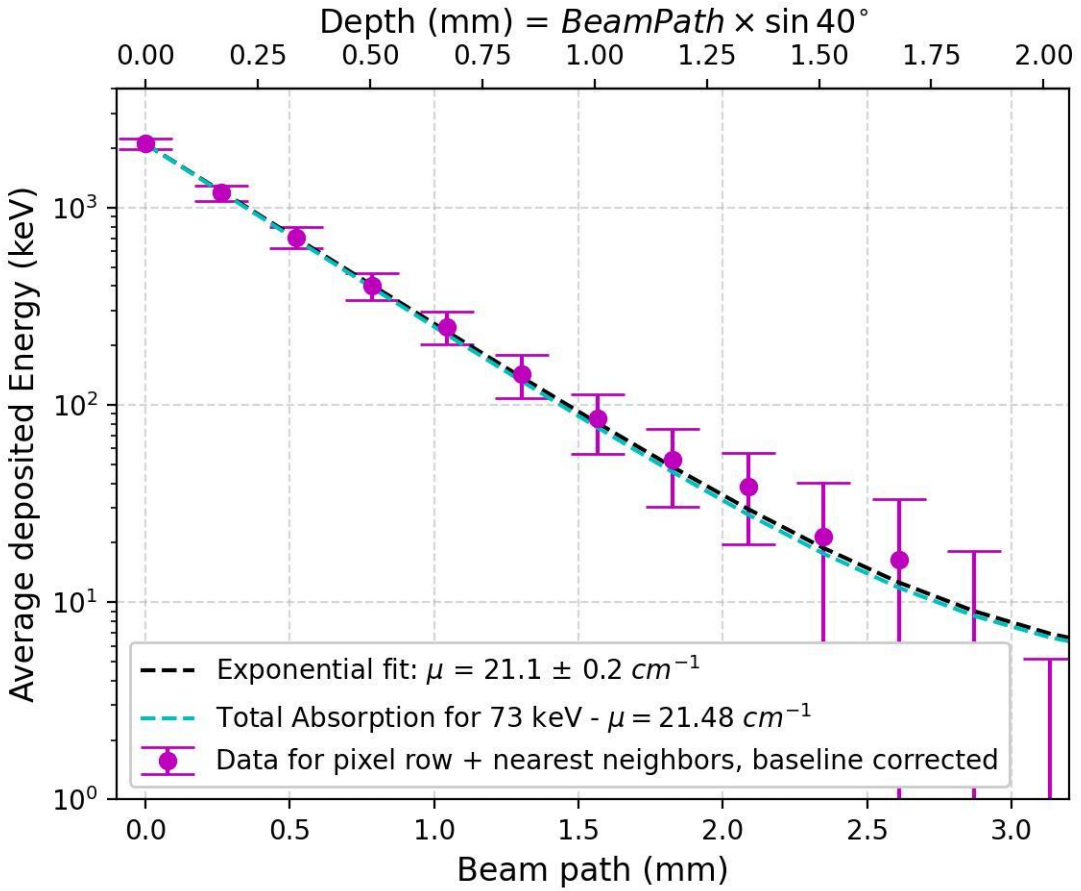


Results: CZT angle-on measurement

Beam incidence at 40°, ~ 7×10^7 ph/s



(log scale)



Results: CZT angle-on measurement

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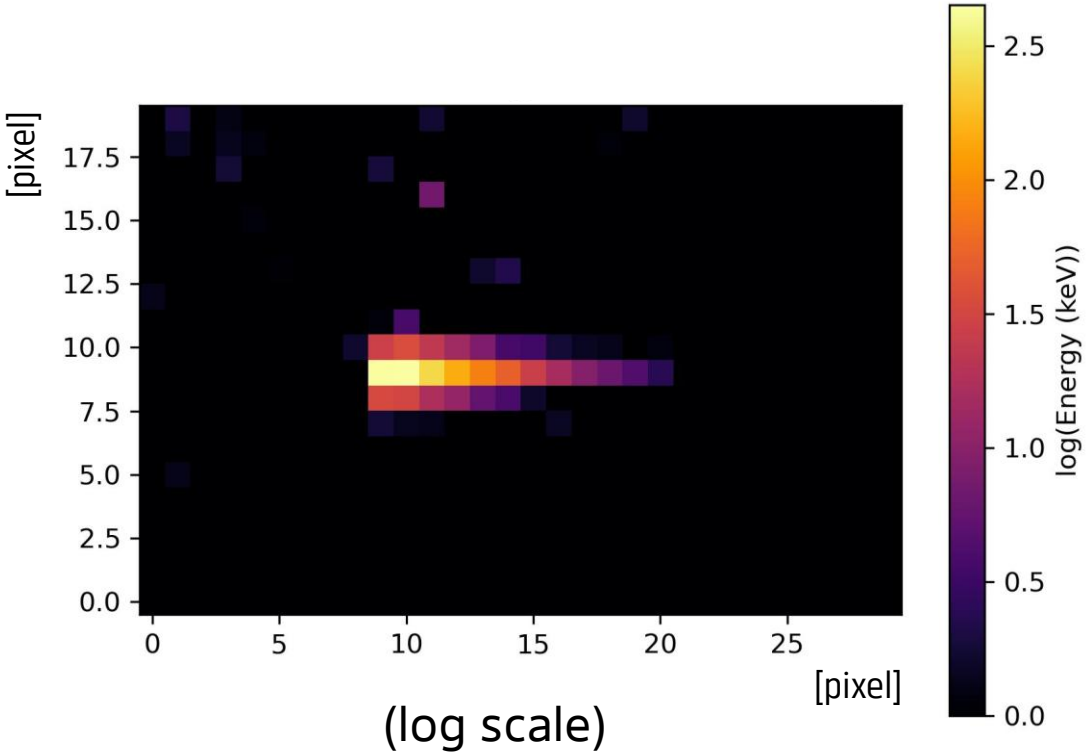
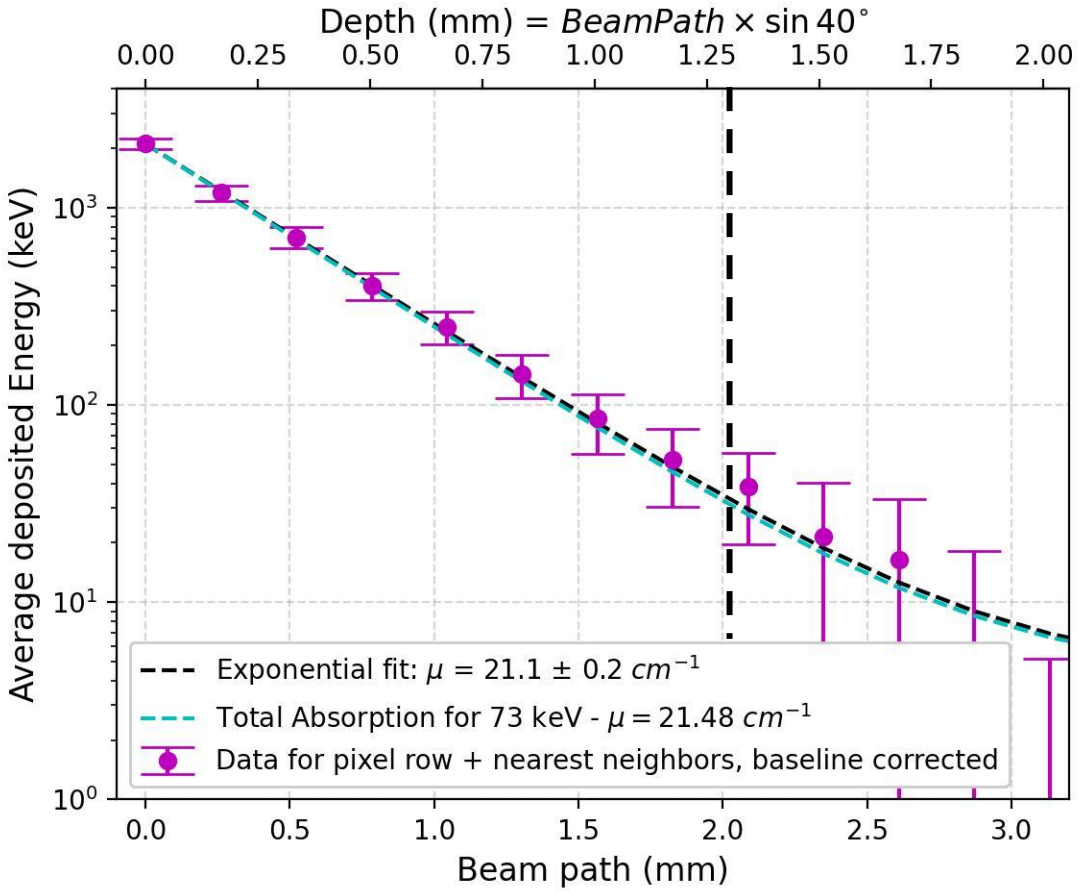


(log scale)



Uniform charge collection observed until 1.3 mm depth

Measuring CZT long-term stability

Goal: check for ageing effects and bias-induced polarization

Quasi-ohmic CdTe

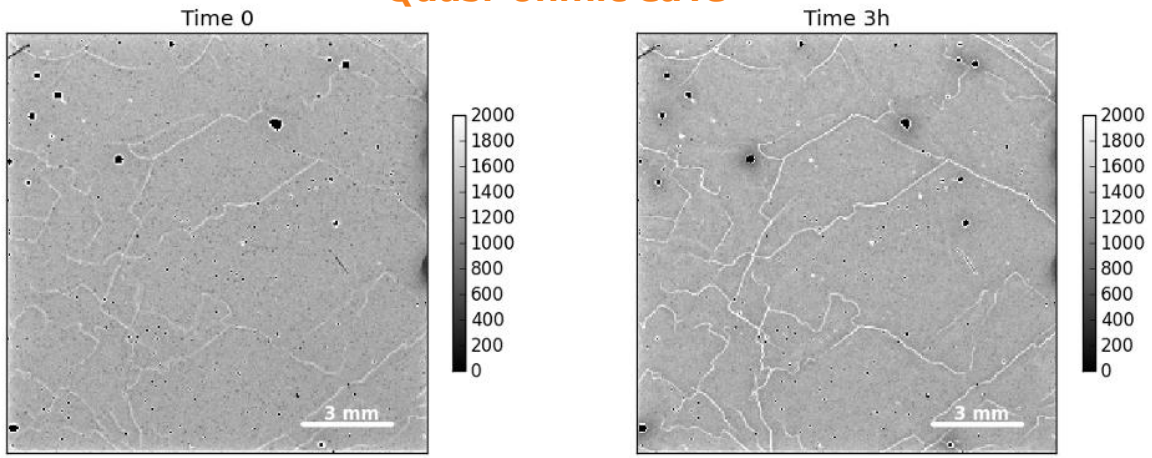
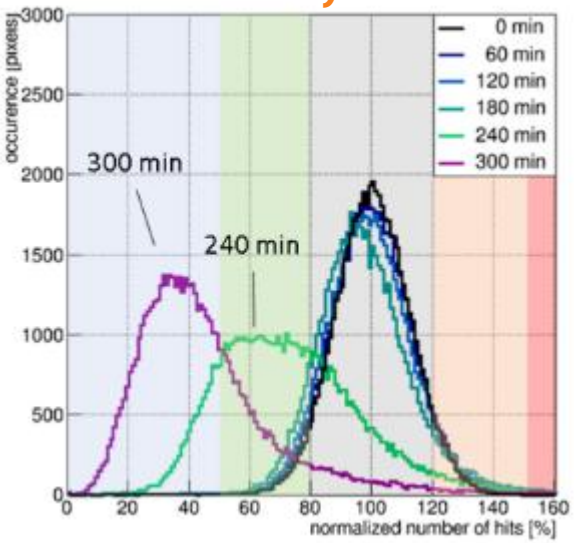


Figure 1. Flood illumination of a single chip CdTe sensor. Left: initial irradiation. Right: after 3 hours of continuous irradiation at 22 keV (incident flux 5.10^5 photons/mm^2/s).

M. Ruat and C. Ponchut. 2014 *JINST* **9** C04030. 10.1088/1748-0221/9/04/C04030

Schottky CdTe

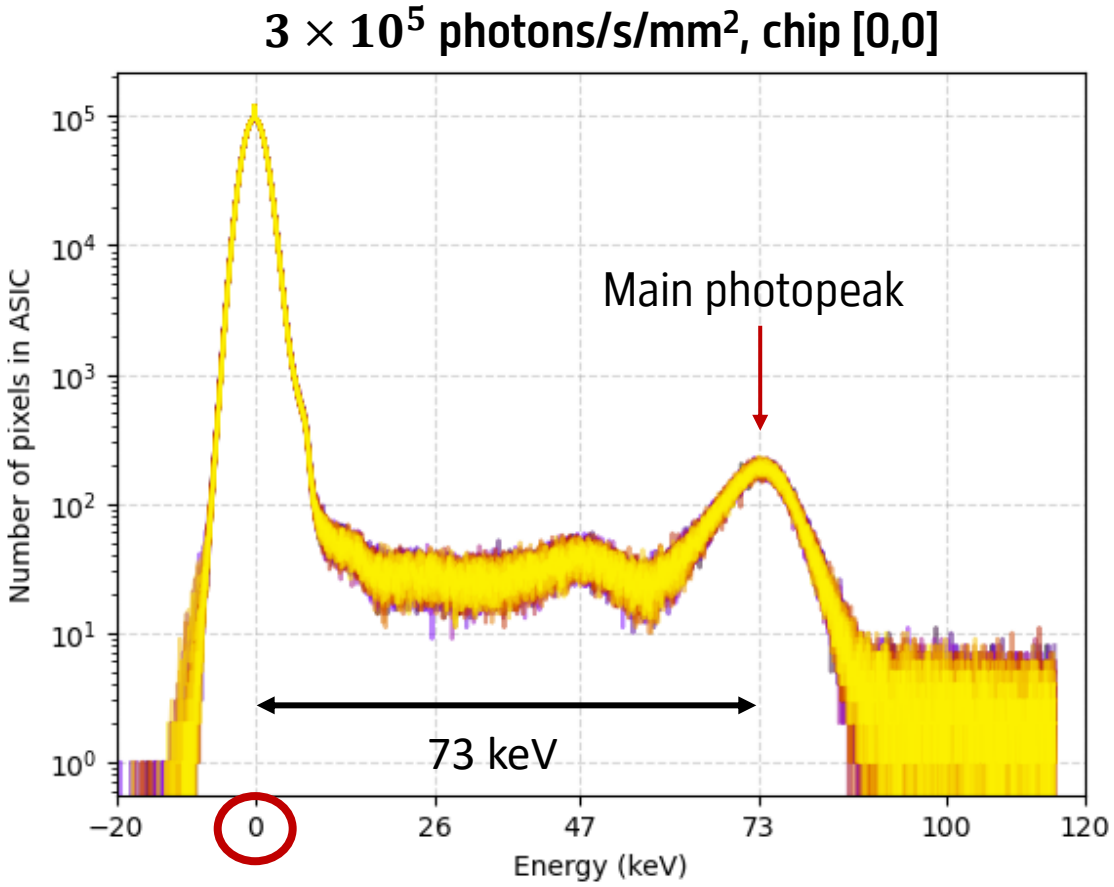


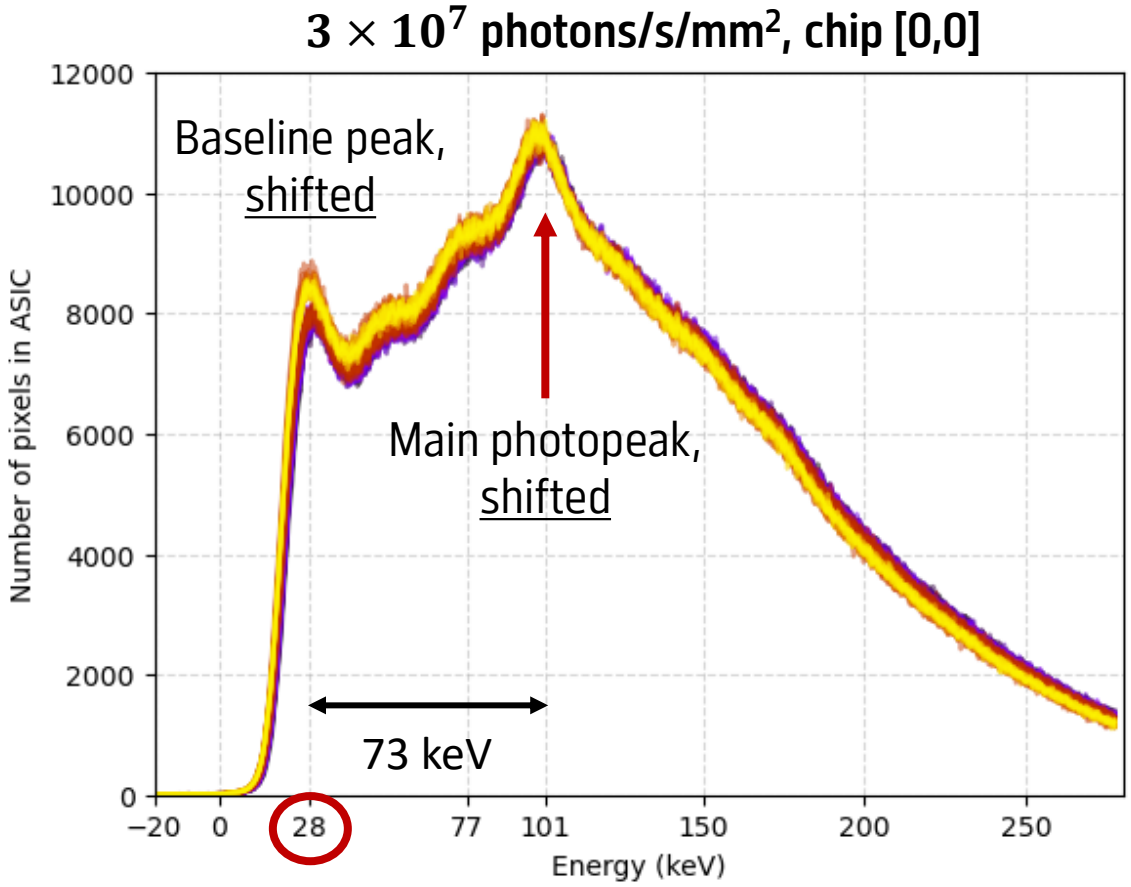
M. Meyer et al. 2022 *JINST* **17** P06035
10.1088/1748-0221/17/06/P06035

Procedure: full-field illumination of the sensor

- Air scattering measurement overnight – 3×10^5 photons/s/mm^2
- Water scattering measurement overnight – 3×10^7 photons/s/mm^2

Results: CZT long-term stability





Compatible with Excess Leakage Current effect described by B. Cline *et al*, 2025

B.D. Cline et al, 2025 *JINST* **20** P10021 10.1088/1748-0221/20/10/P10021

Results: CZT long-term stability

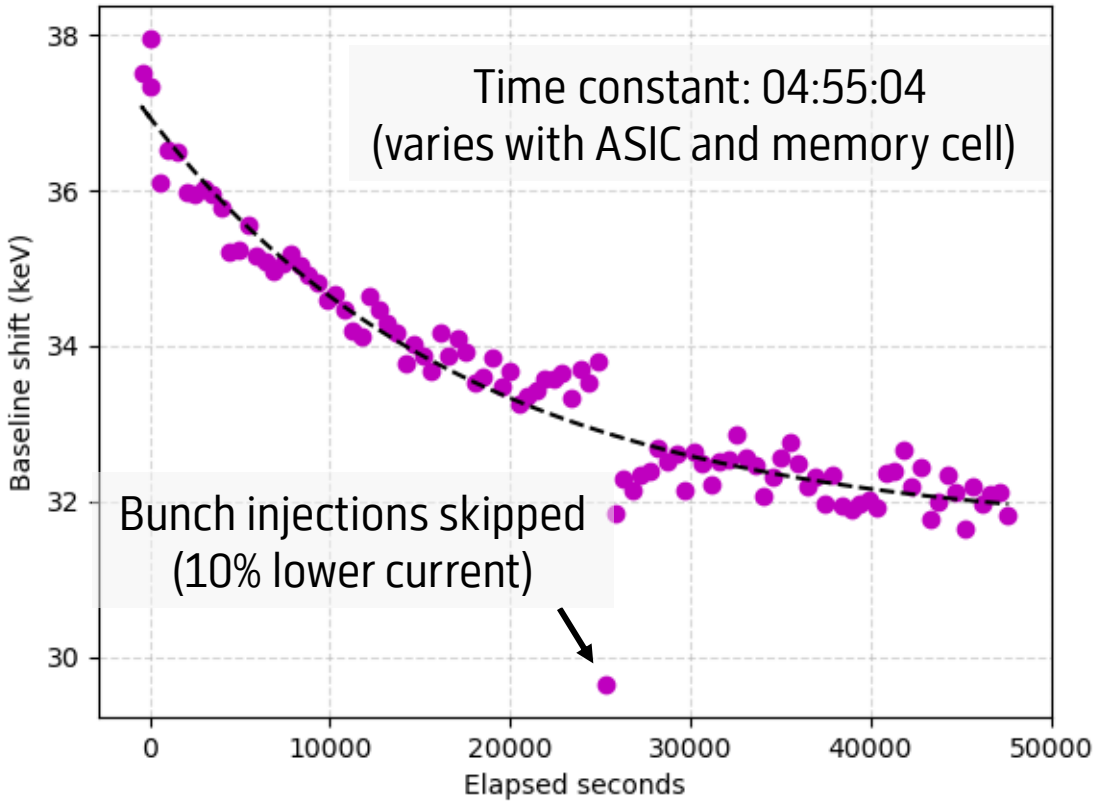
Average flux and Excess Leakage current per ASIC:

1.72 x 73keV photons/frame 23.0 nA/mm²	1.75 x 73keV photons/frame 24.0 nA/mm²
2.03 x 73keV photons/frame 26.6 nA/mm²	2.14 x 73keV photons/frame 30.4 nA/mm²

73 keV beam

Flux and baseline shift: correlation of 0.87

Water scattering, 3×10^7 photons/s/mm²
Chip [0,1]



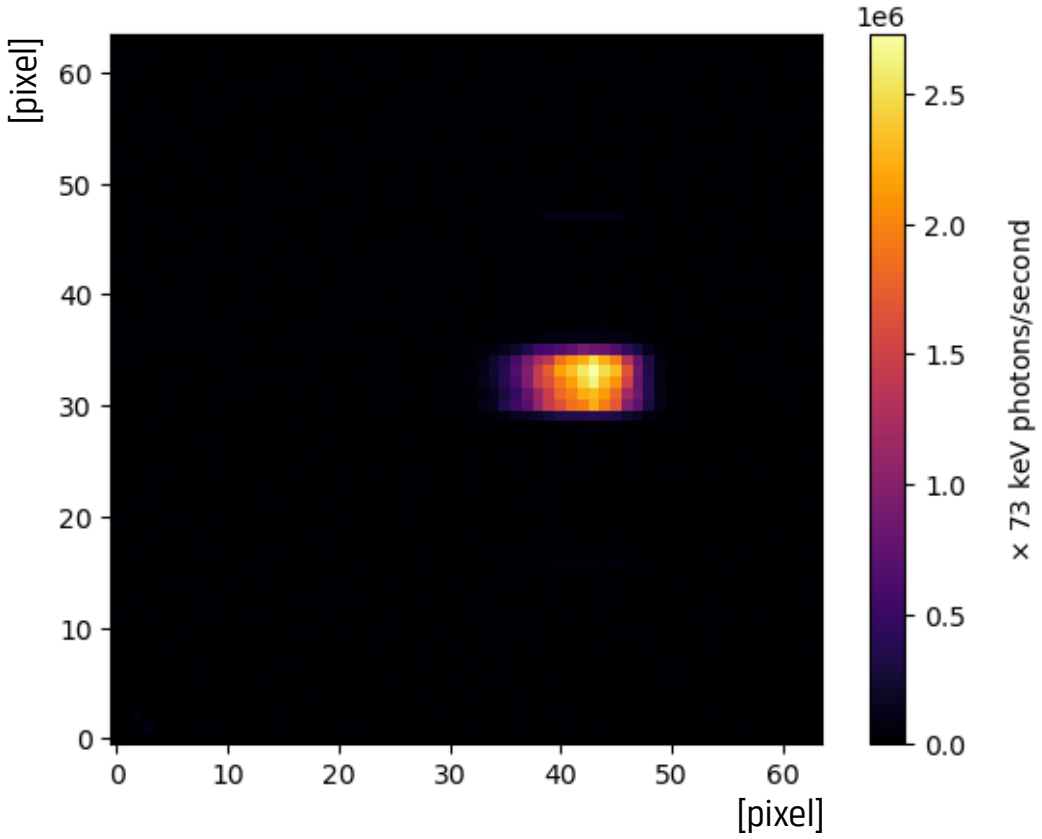
Measuring Excess Leakage Current

Dedicated measurements of Excess Leakage Current:

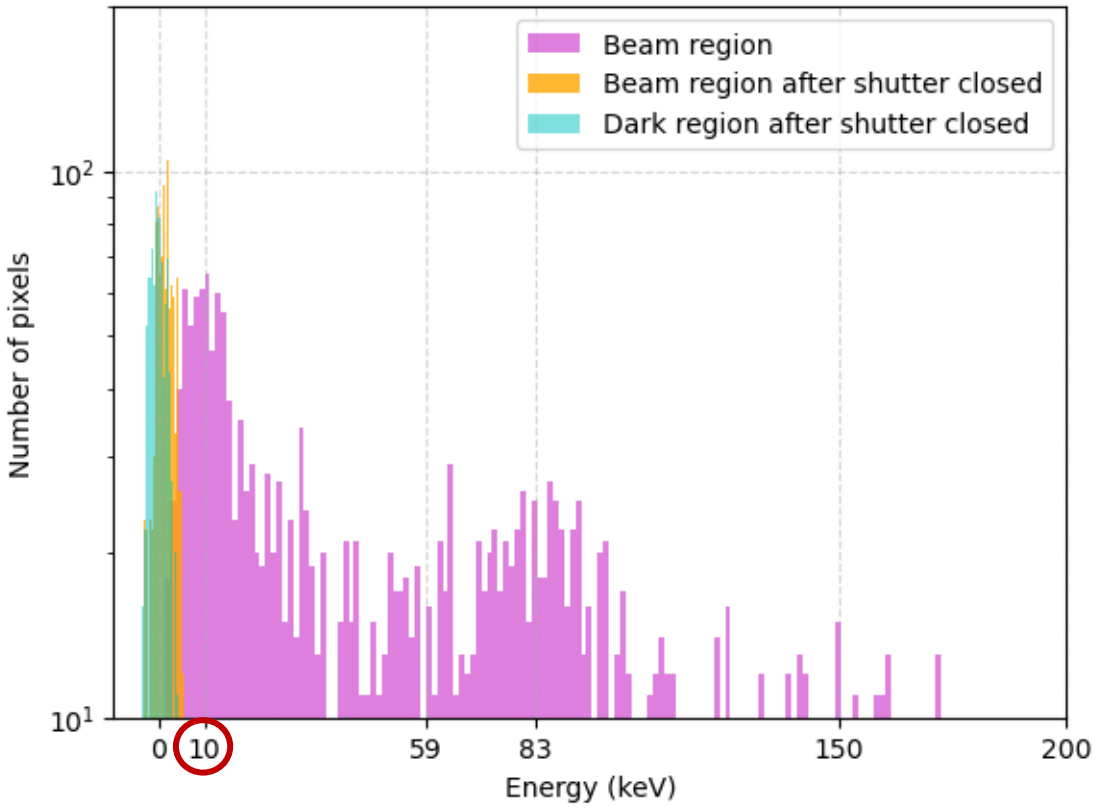
- Exposure for 200 seconds, then closing the shutter
- Measuring for 300 seconds (200+100s in the dark)
- Check for baseline shift during irradiation and after shutter closed
- Different attenuators, different gains, focused (10x2 μm^2) and unfocused (2x1 mm^2) beam

Results: CZT Excess Leakage Current

Unfocused beam, $\sim 4 \times 10^7$ photons/s/mm²



$dark_{beam_area} - dark_{nobeam_area} = 1.1\ nA/mm^2$

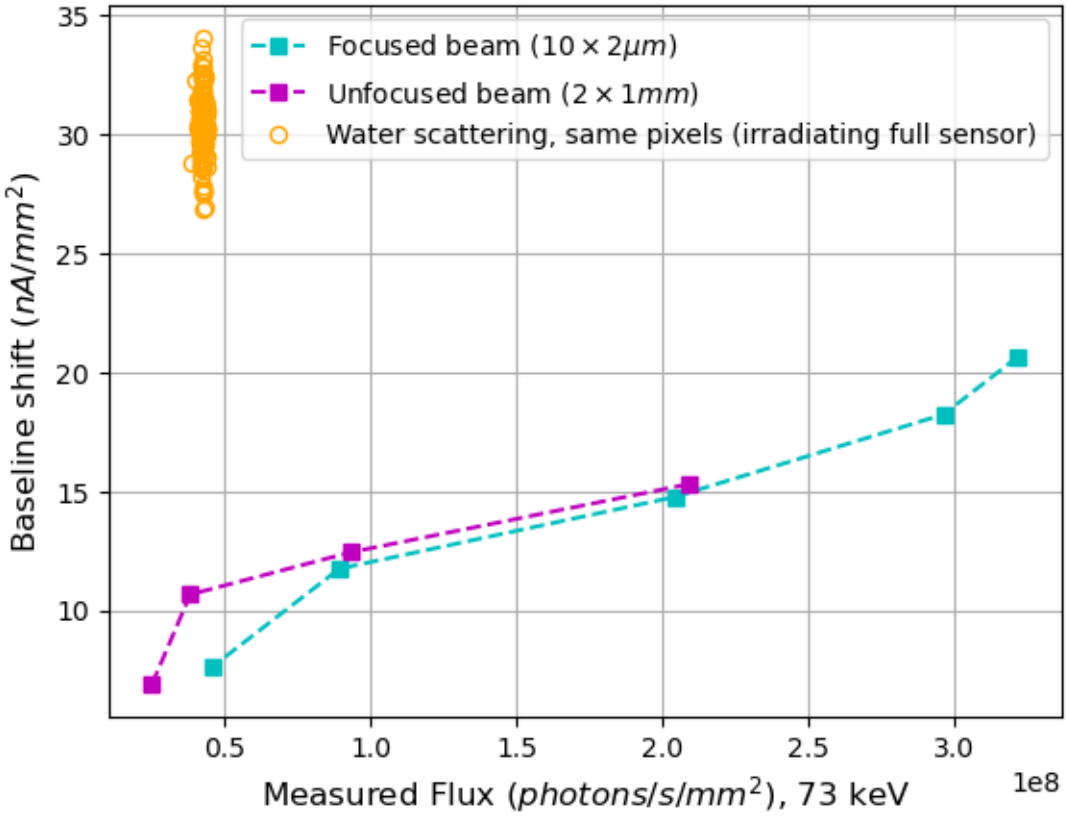


We see the baseline shift, but not after closing the shutter

(likely disappears in the 320 e- RMS noise of AGIPD ~ 1.33 nA/mm²)

Results: CZT Excess Leakage Current

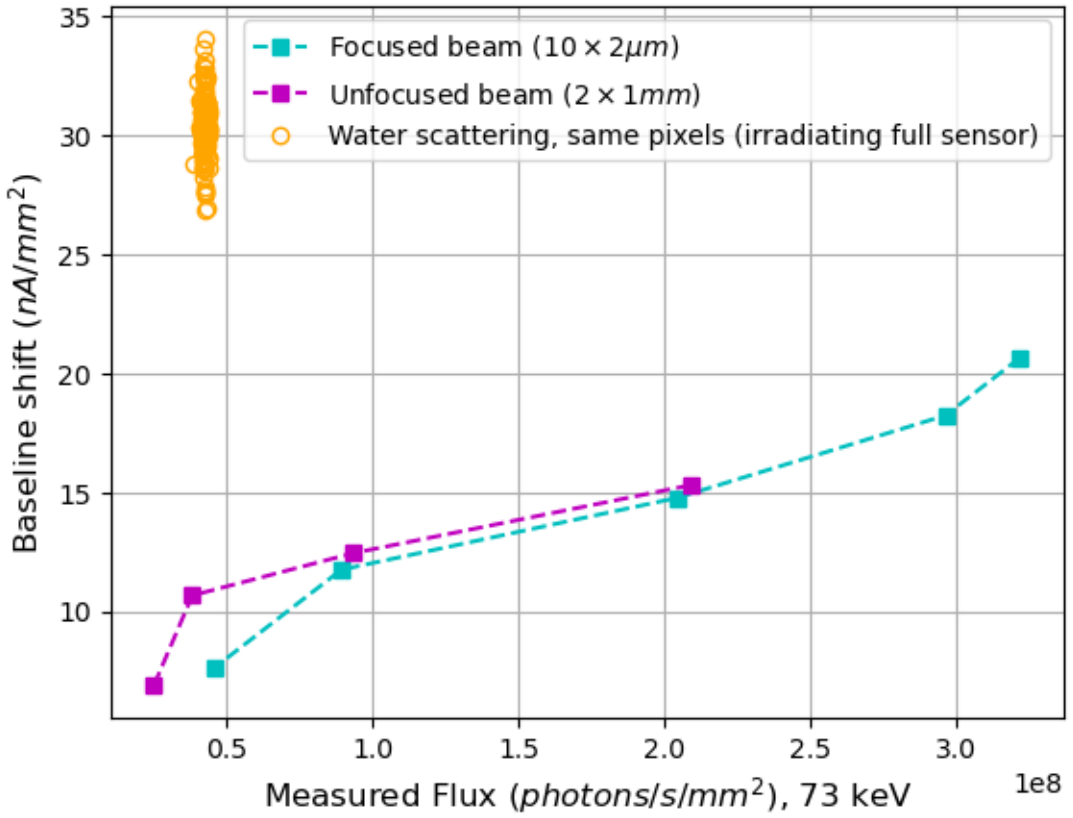
Shift during irradiation, lower intensities



Illuminating the whole area has an impact. ASIC effect?

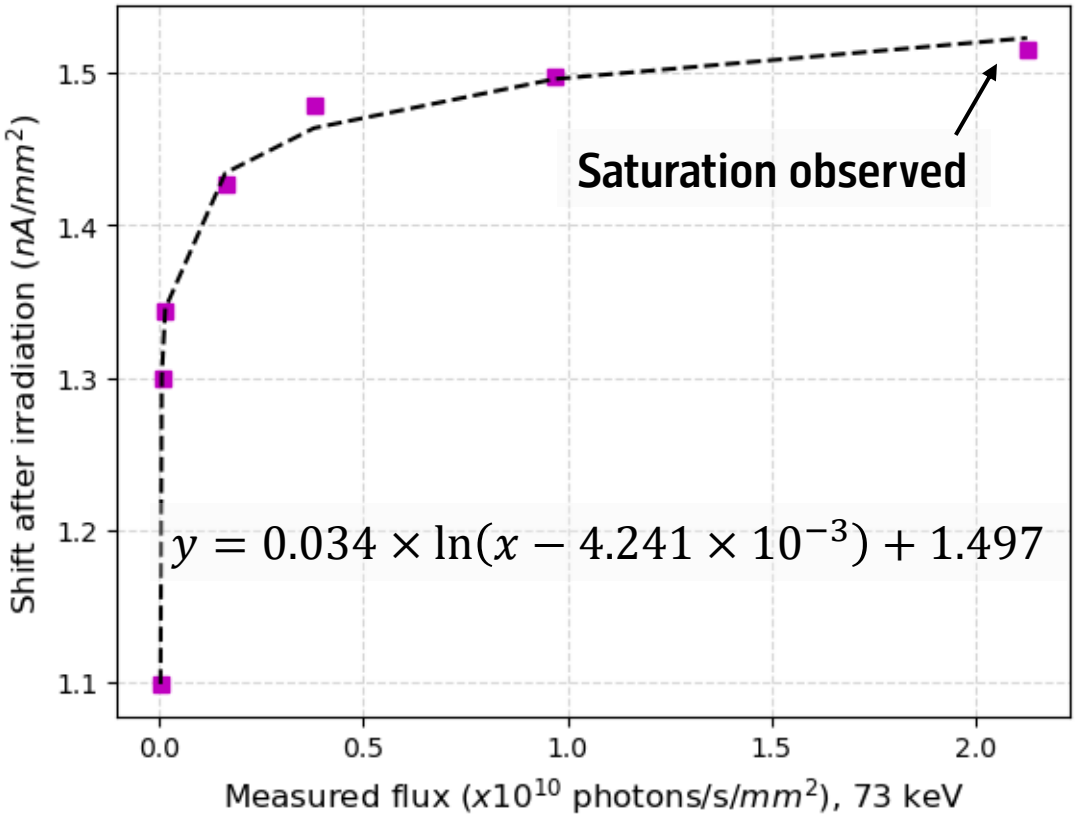
Results: CZT Excess Leakage Current

Shift during irradiation, lower intensities



Illuminating the whole area has an impact. ASIC effect?

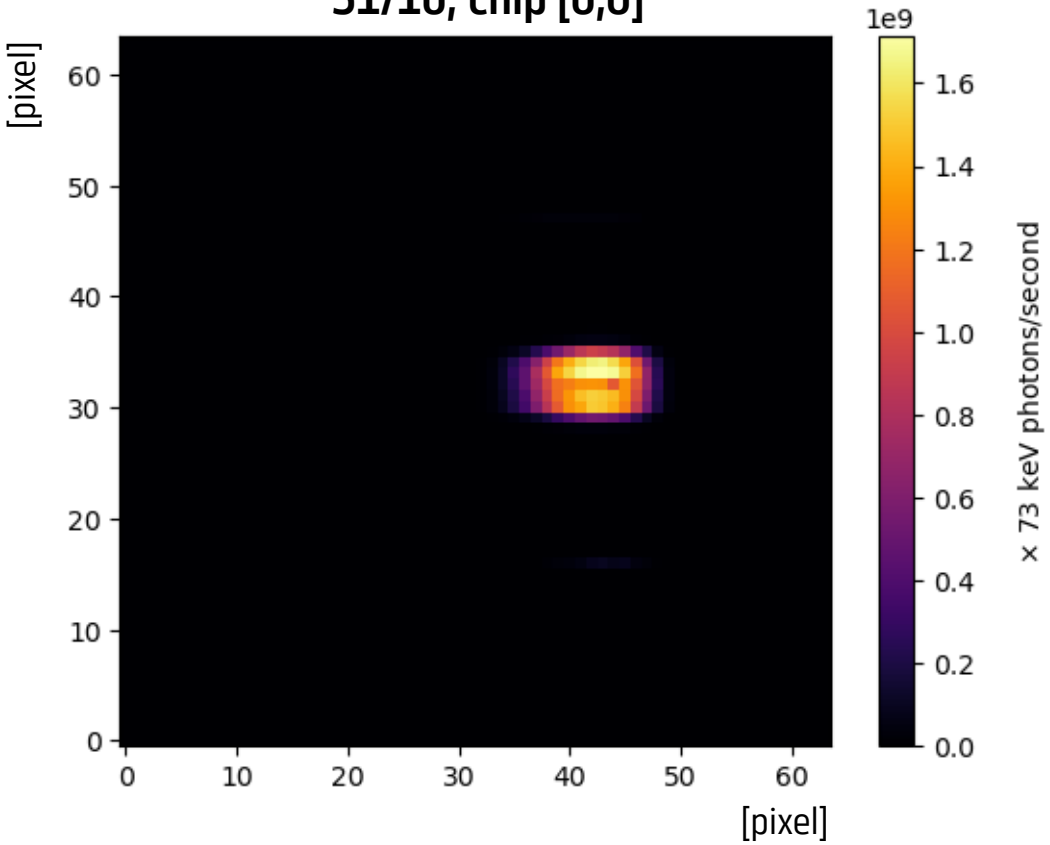
Shift after heavy irradiation, unfocused beam (average of 100 seconds after shutter closed)



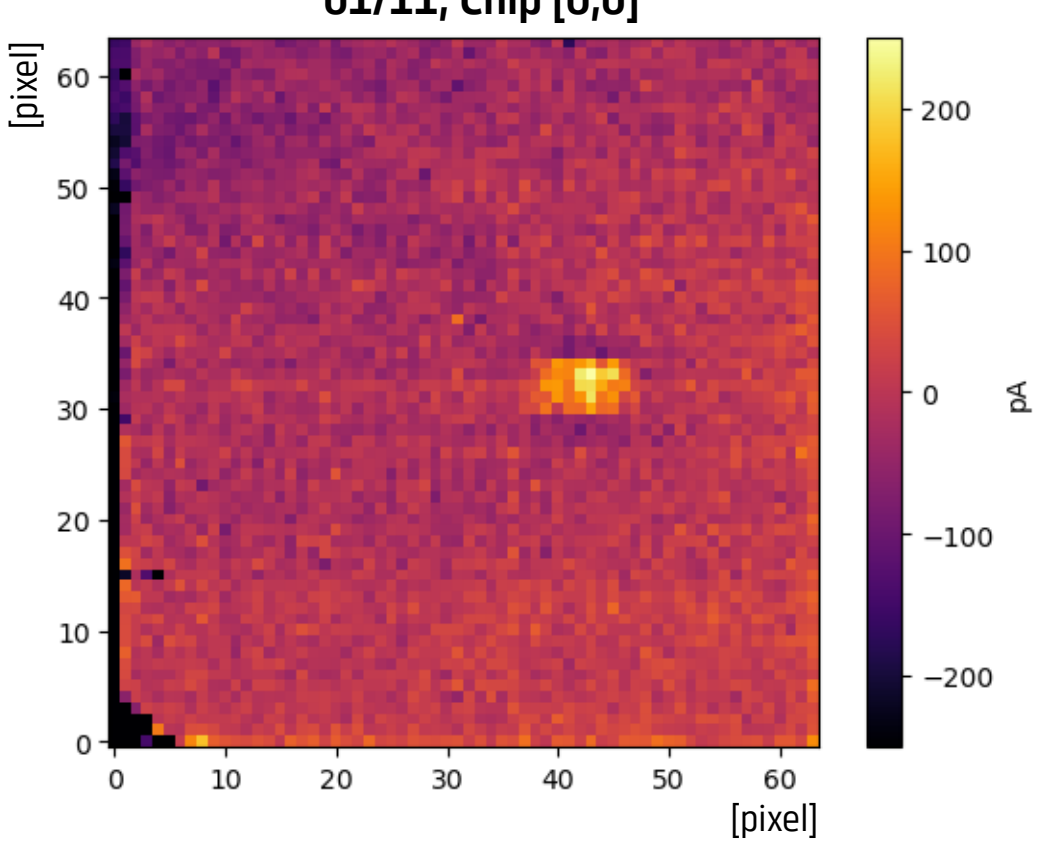
Baseline shift in the dark estimated to 1.55 nA/mm² at 4.25e+10 ph/s/mm²...

Results: CZT high flux tolerance

High intensity exposure, 31/10, chip [0,0]



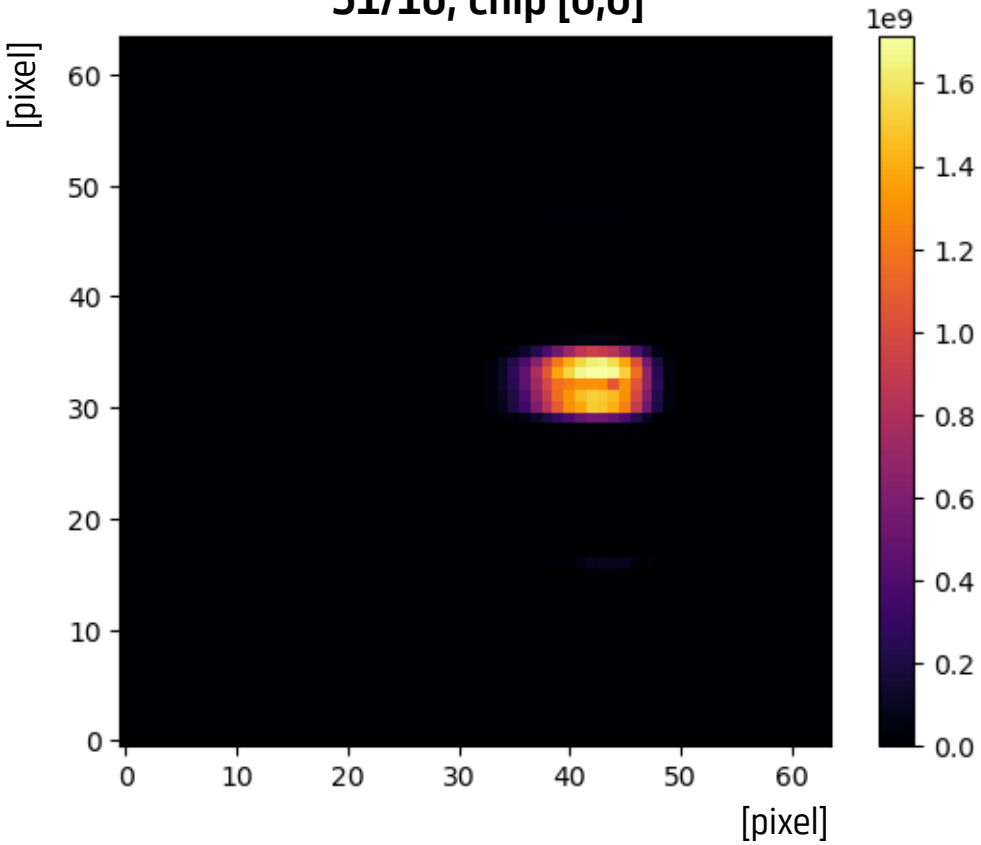
Difference to reference dark in pA, 01/11, Chip [0,0]



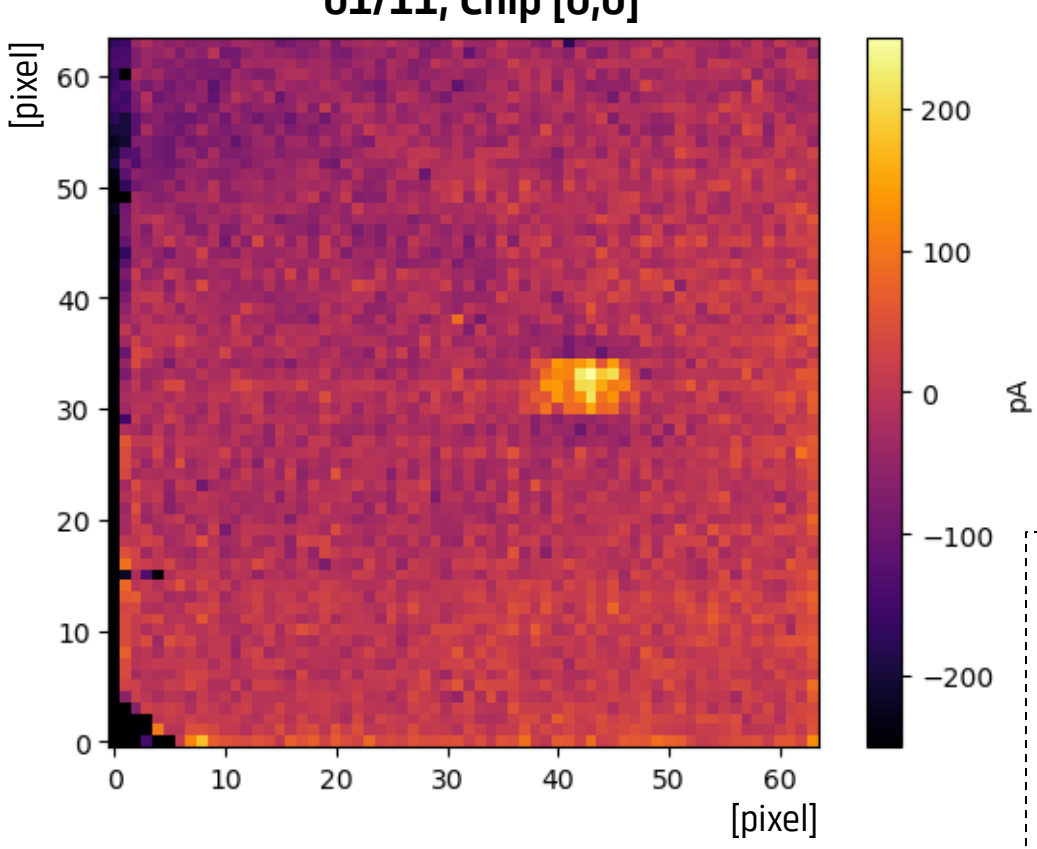
...but 20 hours after exposure to 4.25×10^{10} photons/s/mm² for 200 seconds, higher dark current (average 94 pA/pixel = 2.35 nA/mm²) in the beam area

Results: CZT high flux tolerance

High intensity exposure, 31/10, chip [0,0]



Difference to reference dark in pA, 01/11, Chip [0,0]



…but 20 hours after exposure to 4.25×10^{10} photons/s/mm² for 200 seconds, higher dark current (average 94 pA/pixel = 2.35 nA/mm²) in the beam area

Comparable to effects observed for **Schottky CdTe** sensors at 20 keV by M. Meyer et al. 2022 *JINST* **17** P06035 10.1088/1748-0221/17/06/P06035

Conclusion and Future Prospects

No absolute show-stopper was observed

- Sensor could handle 1 MHz operation and fluxes up to 4.25×10^{10} photons/s/mm^2
- Difference among pixels can be corrected with dark and flatfield calibrations
- Good charge collection at different depths of the sensor
- Uniform electric field in the pixels (less than 10% deviation)

- Excess Leakage Current observed for higher fluxes
  - Could impact the detector dynamic range at HG
  - Varies with the exposed area and over time
  - Very hard to diagnose and correct with AGIPD

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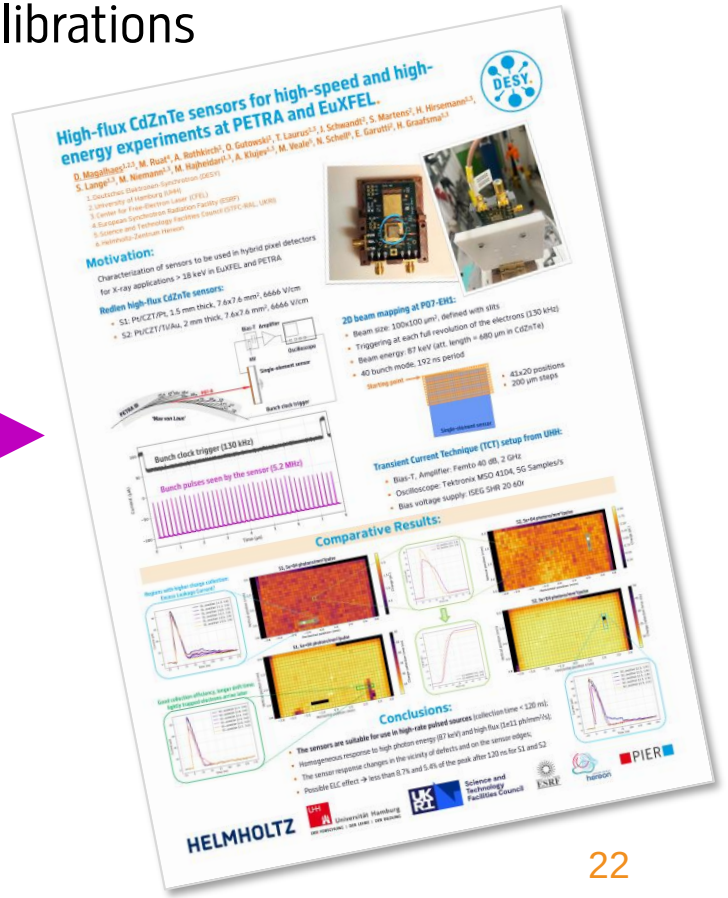
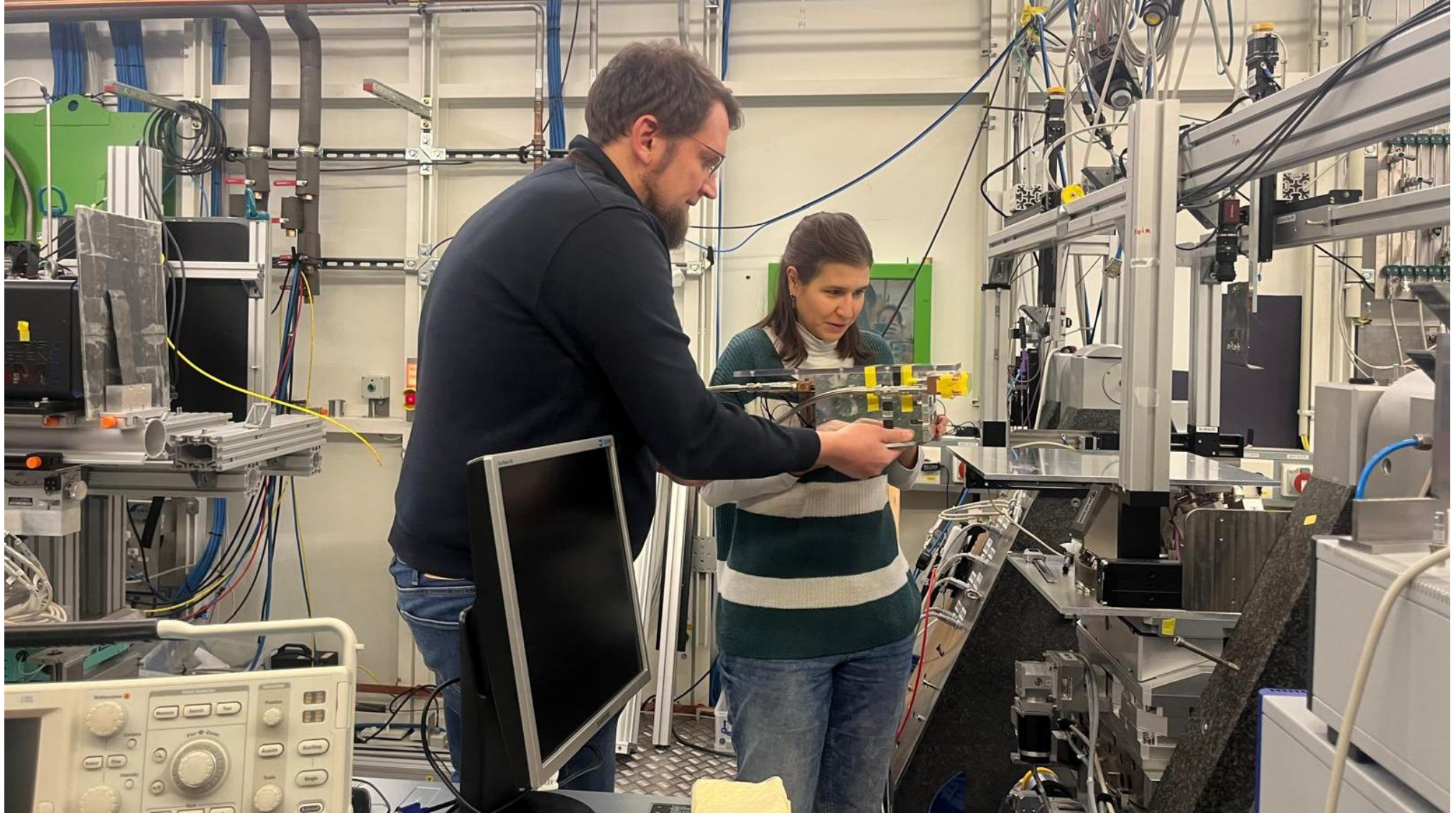


Conclusion and Future Prospects

A full module composed of 4 high-flux CZT quads is under assembly

- Aims at testing the module during friendly-user experiments
- Allow for in-situ evaluation of impacts on the data

- More beamtimes to come at HED/EuXFEL (08.2026, proposal for 2027)
- A module with p-type Si sensors + ecAGIPD for direct comparison is planned for 2027

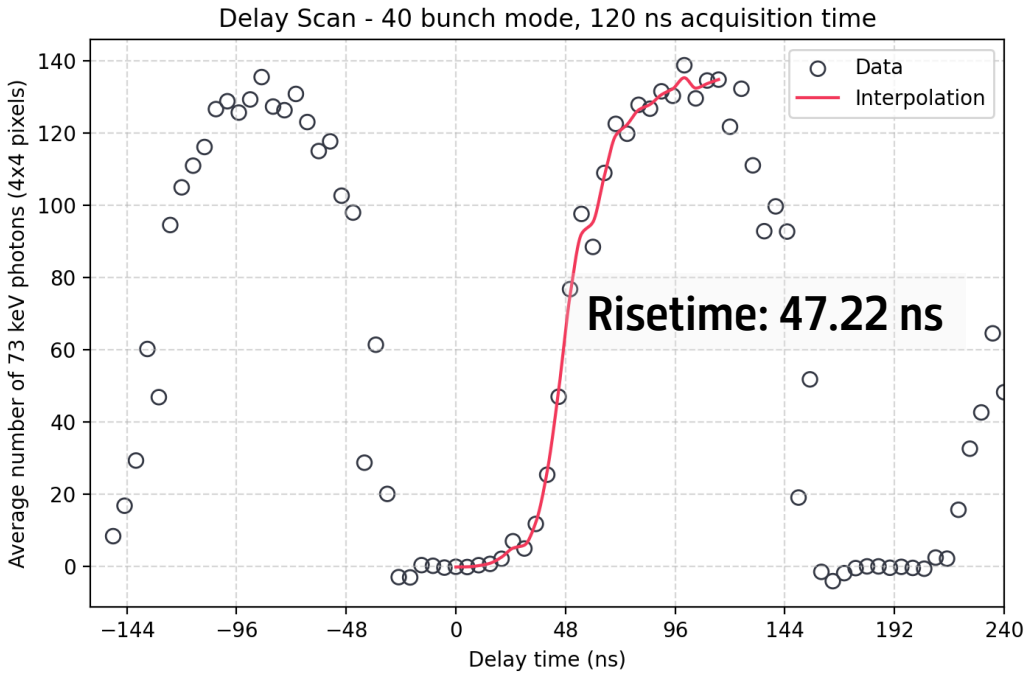


Thank you for your attention!

Backup slides

Setup

- AGIPD: fixed 960 ns acquisition time (5 bunches), waiting 960 ns between frames
- Each frame sequence triggered by the Petra III bunch clock (full revolution of the electrons = 130kHz)
- Delay setting for fine synchronization
  - individual bunches observed scanning the delay with 120 ns acquisition time
- Synchronization observed to hold well for the first 100 frames
  - 100 memory cells used per frame sequence (“train”)



Results: sub-pixel mapping

- Focused beam (10×2 µm), fly scan, motor speed 0.08 mm/s in vertical
- 200 trains per column, 10 µm steps between trains, 100 frames per train
- 211 columns, 10 µm steps between columns → 10×10 pixels
- Plotting the maximum deposited energy in the area
  - Highlights the pixel edges due to charge-sharing

Results: angle-on measurement

Motivation: previous depth-dependence of CCE observed in High-Z sensors

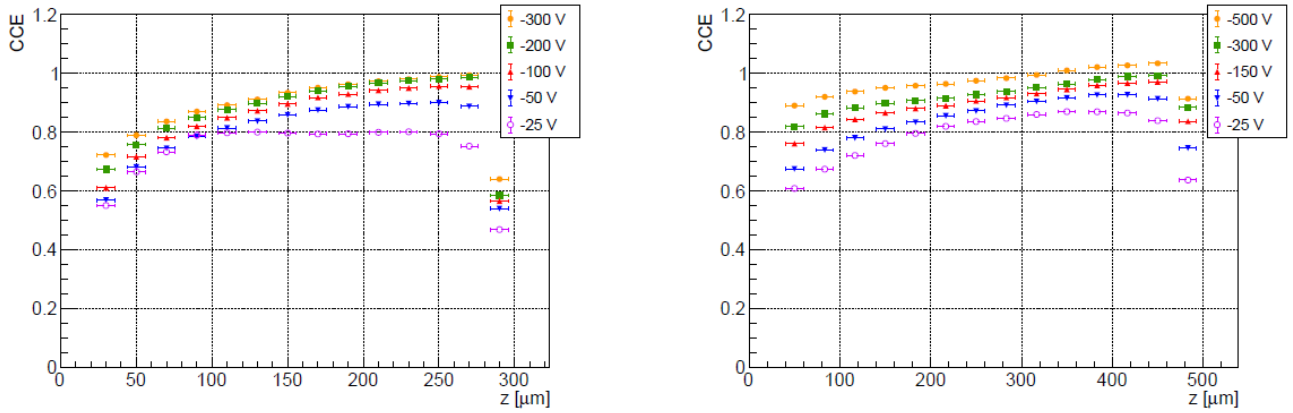


Figure 6. Experimental dependencies of the charge collection efficiency of electrons on the interaction depth z for the 300 µm (**left**) and the 500 µm (**right**) thick detectors.

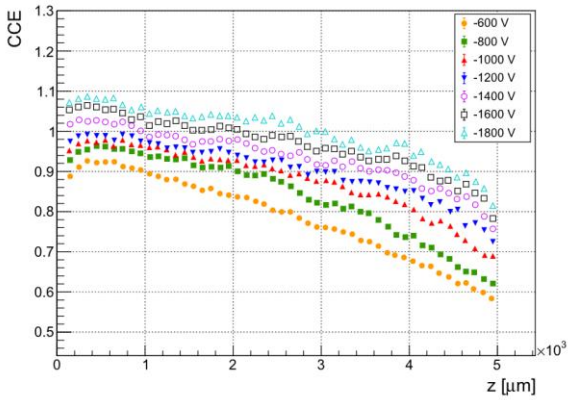
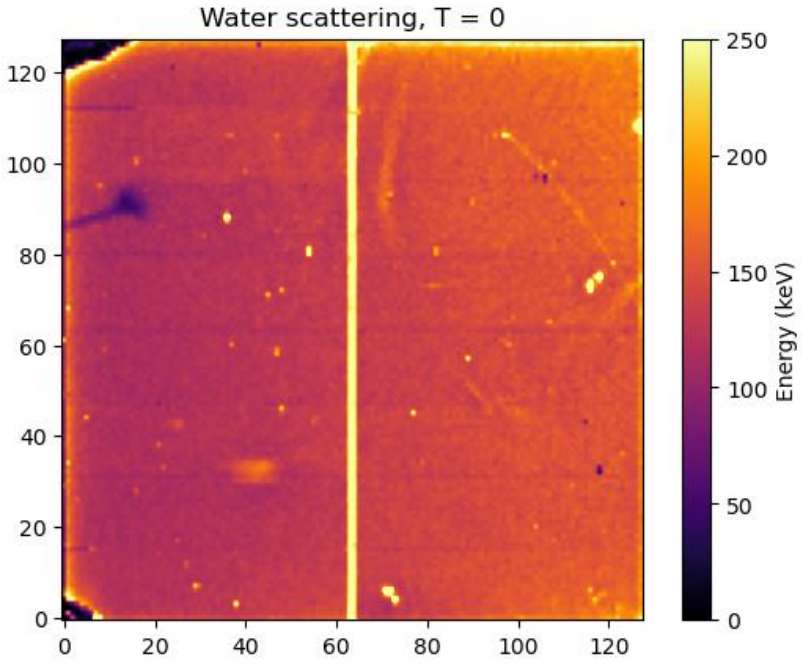


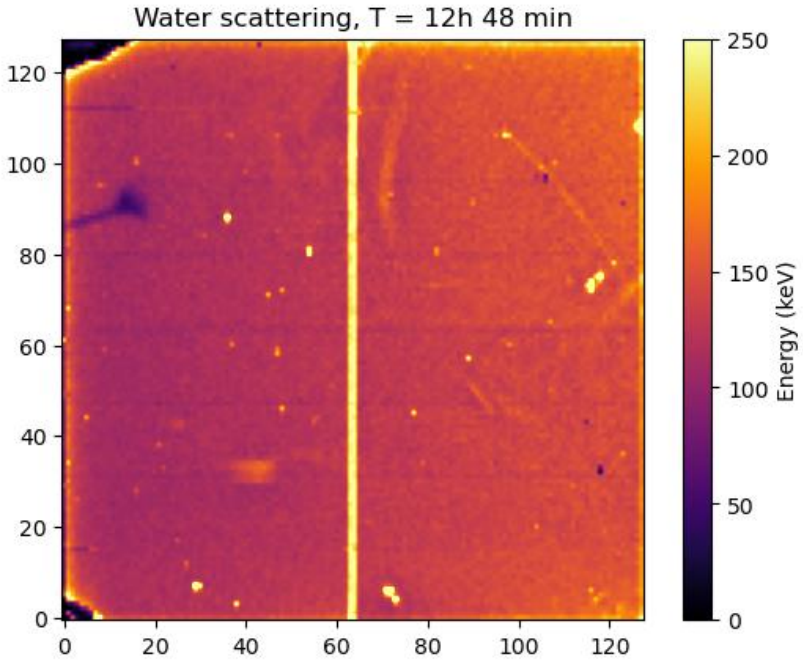
Figure 8. The dependence of the charge collection efficiency on the interaction depth for different bias voltages. Coordinate $z = 0$ μm corresponds to the pixelated side of the detector.

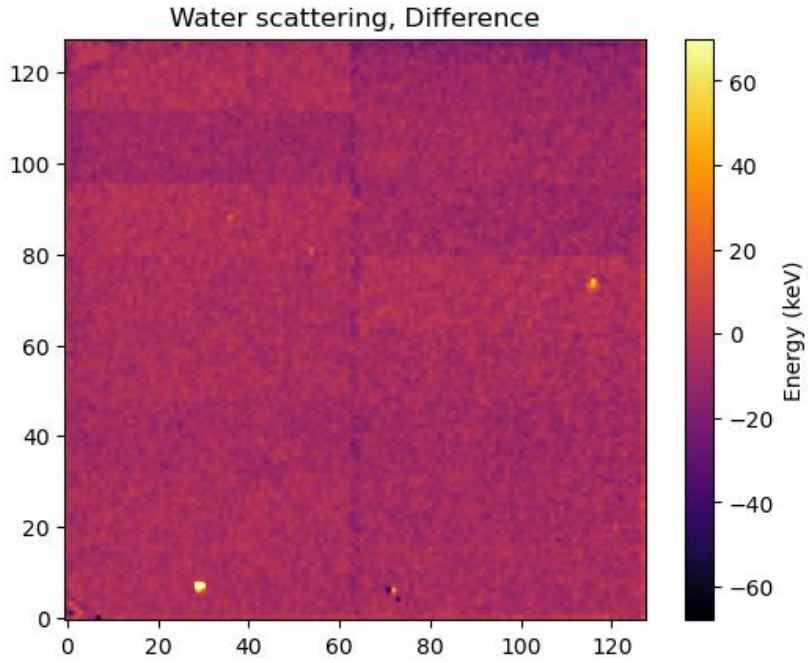
10.3390/s23156886
For GaAs, 2023

10.1088/1402-4896/ad10dd
For CZT, 2024

Results: long term stability

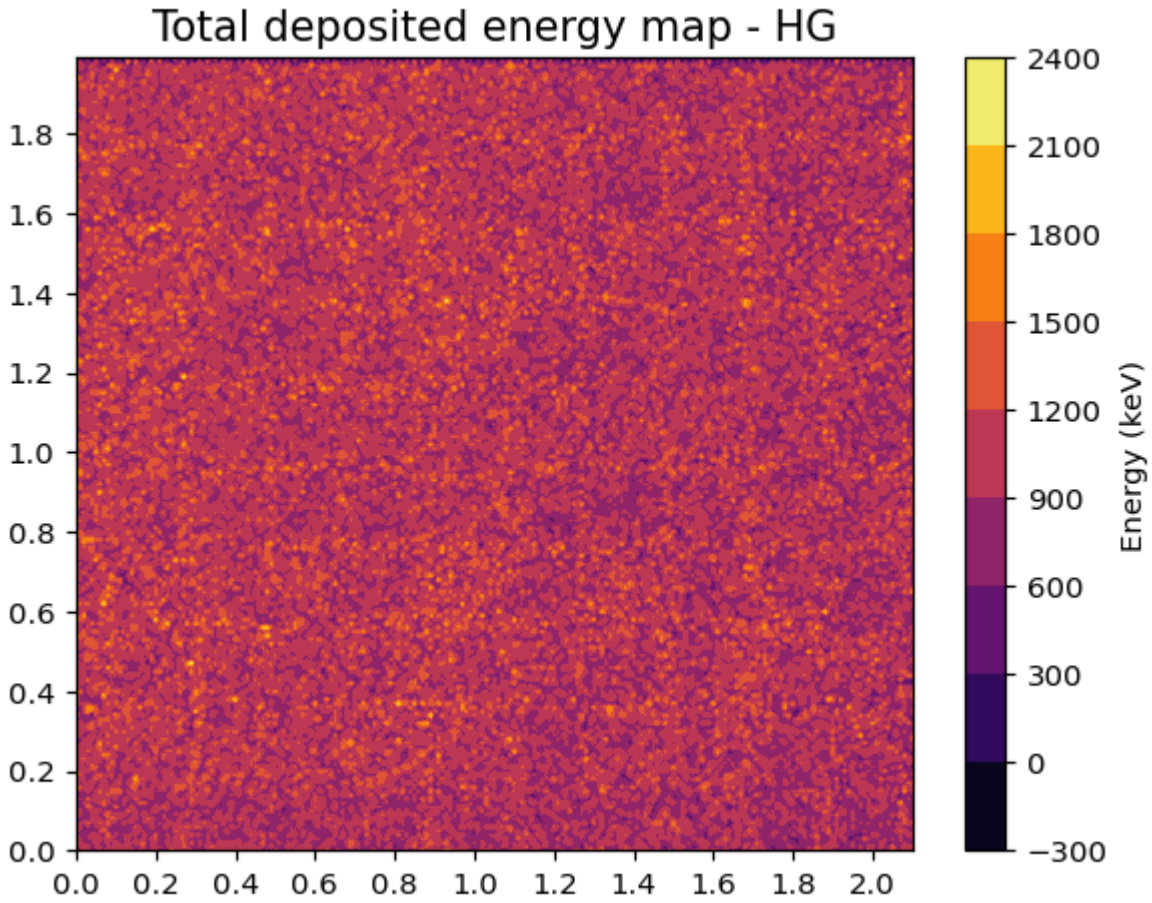
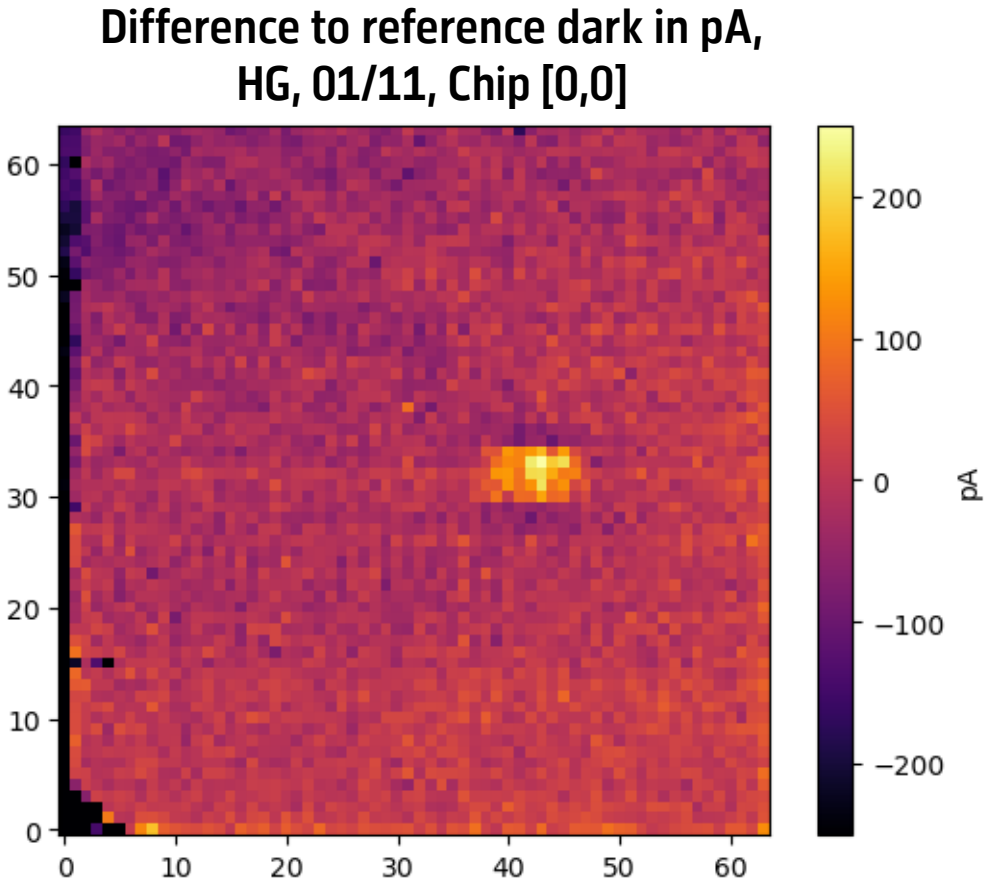
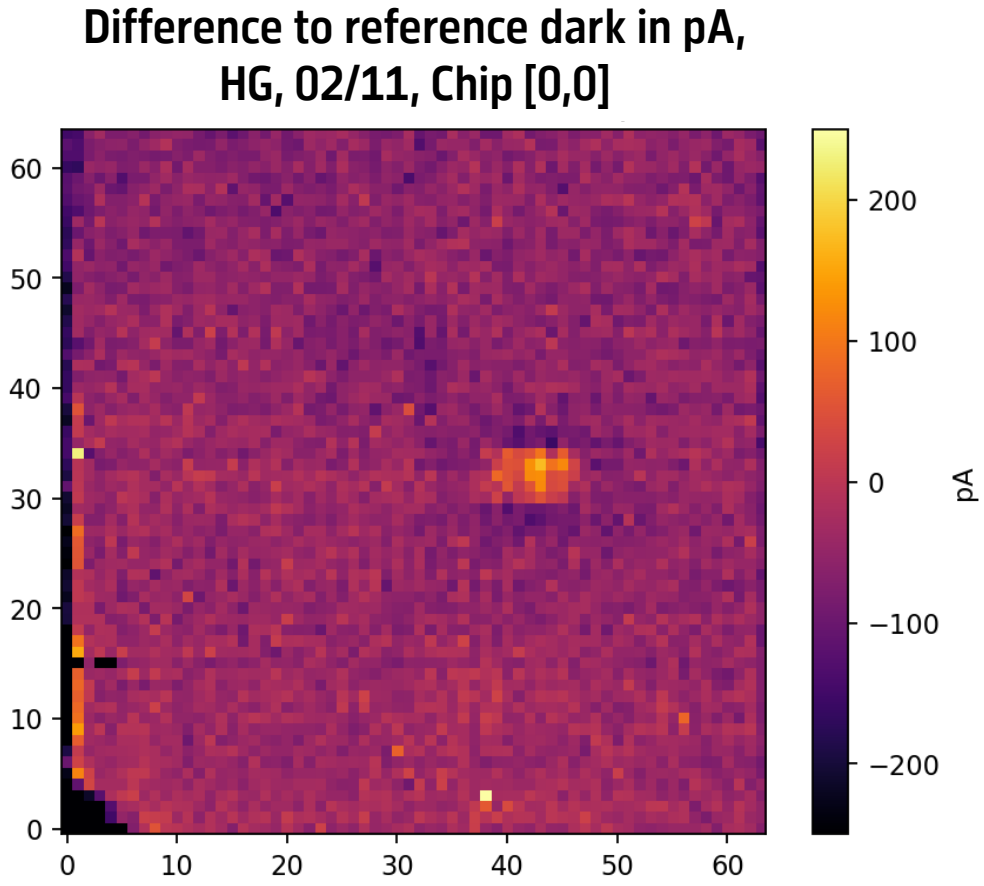






Results: sub-pixel mapping

Summing the signal in the area:



Results: CZT high flux tolerance